Economic and Information Principles for Cargo Delivery Management in Global Network Supply Chains

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Summary
The study is devoted to the formation of a economic principles cargo delivery management in global supply chains. Mathematical model of delivering special categories of goods by road is a key element of these principles. The article analyzes the existing studies on solving the problem of cargo delivery in various aspects. It was noted that the greatest attention is paid to legal regulation, last mile delivery, optimization of routes and delivery schemes, information support, technological innovations, cluster routing, etc. In the developed mathematical model a minimum of total costs of forming loading units and freight shipments was defined as the criterion of optimality of organizing delivery by motor transport. The authors propose the creation of logistics clusters allowing the integration of urban transport flows and global supply chains.
Key words:
Information aspects, delivery management, logistics clusters, logistics systems.

1. Introduction

The activities of the transport industry largely depend on the development of other sectors of the economy, and, as in other sectors of the economy, the indicators of the financial results of the work of transport have recently been unsatisfactory. Consequently, the primary task of identifying and eliminating negative trends in the development of the transport industry arises, since it is transport that is the most important link in the sphere of economic relations. The actual problem facing the transport industry of Ukraine is the restoration of the previous priority status within the framework of the national economy and the conquest of strong competitive positions in the world transport market. An urgent requirement of the time is to provide each participant in the transportation process with access to accurate information about the condition of the cargo at any time. Many innovations in the activities of transport and logistics enterprises are associated with the development of information and telecommunication systems and technologies. Today it is practically impossible to provide the quality of service and efficiency of logistics operations necessary for consumers without the use of information systems and software systems for analysis, planning and support for making management decisions. Moreover, it is thanks to the development of information systems and technologies that have made it possible to automate standard operations in transport and warehouse processes that logistics has become the dominant form of organizing goods movement in the highly competitive markets of transport services.

Solving the problems of organizing the delivery of special categories of goods is becoming increasingly important in the globalization of supply chains. The role of the interaction of modes of transport in such deliveries is growing, and the road transport is becoming irreplaceable for deliveries according to the “door to door” logistics principle. Road transport in supply chains performs the role of the final (sometimes initial and final) element, ensuring the delivery of cargo to the final consumer, i.e. the last mile. This segment of the supply chain is one of the most important and complex, and therefore requires additional research and theoretical substantiation in particular the development economic principles cargo delivery management in global supply chains. Attention should also be paid to the possible risks that arise when organizing the delivery of special categories of cargo. These risks often occur at the intersections of transport modes, during transshipment, warehousing and consolidation processes. They can be minimized or insured, thereby protecting from possible losses. Another difficulty of delivery is that in some cases the actual value of the cargo itself is relatively small, but the value of that shipment for the effective supply chain operation is incomparably higher. So, standard approaches to declaring the value of cargo and its traditional insurance become useless, which means that the logistics operator is required to ensure delivery under such non-standard conditions, relying on its practical experience and certain

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organizational, economic and technical-technological solutions. There is also the question of what level of integration should be the logistics operator providing such delivery. Is level 3 PL sufficient for this? Or should this be the level of a supply chain system integrator providing integrated logistics solutions and comprehensive logistics services and supply chain management? The authors will try to provide answers to these questions in this study.

General approaches to the organization of cargo delivery differ significantly depending on the country and type of cargo. Delivery time arrangements are often implemented on the basis of contractual obligations under the relevant contact [1], but there are other possible options for determining this aspect. The logistics management element is a key component of a company's success as a whole. In general, there is a number of interesting scientific researches devoted to the analysis of legal aspects of the cargo delivery organization. The work of M. H. Abadi and A. A. Kalkoshki [2] should be singled out, in which the authors made an attempt to analyze the components of the United Nations Convention on Contracts for the International Sale of Goods.

The modern market of logistics deliveries is characterized on the one hand by the intensification of IT development [3], and on the other hand the implementation of a client-oriented approach is carried out, and therefore deliveries on the "just in time" principle are becoming more and more popular. The spread of e-commerce has led to an increase in the number of B2C supplies [4], but there are significant obstacles along the way. Last mile deliveries in general are now extremely relevant issues, which is confirmed by studies [5-7] and require theoretical research and justification.

The paper by O. Ozturk and J. Patrick [8] is interesting for the offered new concept of freight transport within the city with the urban railway transit system which has become an alternative mode of freight transport through cities. Significance of the study is also determined by the original two-stage use of approximation algorithm and pseudo-polynomial algorithm of dynamic programming to solve the problems, as well as the heuristic method. Reliability of the supply chain in urban logistics is also extremely important. One of the ways to improve urban freight logistics is the use of special mobile applications [9] requiring appropriate improvements, especially technological ones.

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2. Methodology

In the scientific study the authors used methods of system analysis, expert evaluations, branch and bound method, as well as nonlinear programming and local optimization. The problem of servicing global supply chains within cities is also extremely relevant and requires comprehensive research. In general, there is no serious difficulty in the delivery of the vast majority of special categories of cargo in cities. Their transportation within urban boundaries requires only strict compliance with transportation requirements. However, there is a need for complexity in the delivery of such cargo categories, which requires an effective system of logistics centers. Integrated logistics clusters are one of the leading systems of such centers.

Identification of innovative determinants to intensify the development of regional economic systems [10], the strategy of innovative and intellectual development of the enterprise [11], the implementation of the financial processes evaluation model in the logistics systems of industrial enterprises [12] are relevant researches to determine the preconditions of global supply chain support. The logistics-marketing interaction is investigated by A. Galkin et al. [13], while eco-logistic interaction is studied by A. Galkin et al. [13].

Interesting are studies concerning the competition between modes of transport and determining the most effective under certain conditions, as well as solving problems within the framework of improving urban ecology. A scientific study by S. Chandra et al. [14] is devoted to the development of a mathematical model to optimize the planning of coastal shipping routes according to a certain multimodal distribution scenario. The authors analyze in detail the change in the method of cargo delivery from the original road to the proposed - coastal shipping. The extreme importance of such research, among other issues, is determined by environmental factors in the development of countries and is becoming increasingly popular in developed countries. The authors propose a mathematical toolkit for solving such a problem in India and note that further transition to modal transport is possible with the intensification of infrastructure investment renovation and a significant reduction in the costs of shipping and port operations. Within the study presented by A.V. Ormevik et al. [15] a multiphase capacity assessment model to obtain a modal shift from road to sea in cargo distribution was proposed. Calculations on the model performed by the authors showed that the implementation of a multimodal distribution network with small electric vessels would reduce the need for road transport by almost ¼, with little change in costs and significant benefits for the urban environment. In continuation of similar studies the paper of M. Tamannaei et al. [16] should be noted, where the authors analyzed the competition between the two systems of freight transportation, including road and intermodal road-rail transport, as more environmentally friendly. Despite the trends identified by the authors that economic and social sustainability are consistent with each other, but contradict environmental sustainability with government support and improved services of the intermodal system, the latter is more appropriate.

In a scientific study by F. Kellner and M. Schneiderbauer [17], the authors attempted to harmonize the greenhouse gas declaration process for road supply chains. The results showed that distance is the optimal criterion for this. An important study on urban waste removal combined with the use of urban supply chain management principles and environmental monitoring was carried out by M. Zilka et al. [18]. The authors proposed the use of urban tramway transport only in cases of comprehensive switching to alternative fuels.

Investigating the logistics network of intra-regional connection by dry ports using a two-stage logistic gravity model was done by H. Wei et al. The main components of the calculation of the logistics quality of dry ports were analyzed, as well as the mutual influence between different types of ports. Determining the logistical attractiveness of China's inland ports and the formation of system alliance interaction principles for development and cooperation was carried out in the study of H. Wei et al. [19]. General features of air transportation from the point of view of a logistics operator were studied by C. Archetti and L. Peirano [20]. The authors note the contradictions of the optimality and time criteria in mathematical modeling, and that the effectiveness of the model should be assessed by its practical orientation. Realization of a nonlinear multiproduct model of cargo traffic management of the network air carrier allows to optimize the delivery of cargoes in global supply chains in road and air traffic. The solution of other problems of cargo delivery by air transport was considered in the works of W. Bo et al. [21].

Technological optimization of cargo delivery in transport was considered in the study by Z-H. Hu and C. Wei [22]. In the framework of the scientific research of V. Naumov et al. [23] a model for modeling the demand for goods delivery by cargo bicycles in areas with motorized traffic constraints was proposed. A significant level of validity and adequacy of the model should be noted, as well as its ease of use and applied nature. The organization of multimodal cargo delivery requires careful mathematical processing. The designing of a stochastic decision-making model for multimodal delivery along China-Europe routes is an extremely interesting development. The originality of the model is determined by the assessment of risk levels in solving the problem of stochastic planning under the uncertainty of demand, transit time and unloading time. As part of the study, the authors confirmed the effectiveness and sensitivity of the model, which allows to consider it as adequate. The interaction of the participants of urban freight consolidation of different levels was investigated in the article of L. Savchenko et al. [24].

Analyzing recent scientific studies in the field of road transportation, it is reasonable to note the key ones. In a study the authors proposed the forecasting of customer-oriented profit in road freight transportation by combining different machine-learning methods. The research of A. Budak and V. Çoban [25] is devoted to the assessment of the impact of blockchain technology on the supply chain using cognitive maps. The authors took into account risk factors, cost and customer-oriented benefits. The development of an optimal individual pricing strategy for trucking was done in the study of A. Budak et al. [26].

The problem of stock routing is also an extremely relevant problem. In the study performed by C. Archetti and M. G. Speranza (2015), the authors propose to carry out routing, in which the supplier delivers goods within a certain planning period and organizes distribution routes based on the distribution schedule created by the customers. At the same time, the authors defined the optimization parameters for both traditional and integrated management.

In various possible aspects of organizational and economic, technical-technological and systemic nature the problem of delivery of special categories of goods by road has been studied by many scholars. Technical progress has led to the emergence of multi-chamber vehicles, which have greatly simplified the delivery of a wide range of perishable goods by one vehicle and made it possible to offer new approaches to the selection of delivery schemes. The delivery of pharmaceutical products, especially samples and wastes should be considered as one of the most difficult to deliver. One of the most interesting examples is the solution of the delivery issue by solving the problem of cluster routing of cars using asymmetric variable costs.

3. Results

Global supply chains include the complete cycle for the flow of goods from producer to consumer, followed by cycles of consumption and recycling. Special cargoes are goods active delivered in global supply chains. The logistics operator integration level and economic principles cargo delivery management is one of the key parameters for determining the possibility of ensuring the operation of the global supply chain. Meanwhile, the issue proposed for solution is not a problem only for the logistics operator of 4 PL level, and it can be solved by 3 PL operator under certain conditions. Identifying these potential terms of minimum admission to a given global logistics chain is one of the objectives of the study. When solving the problem of special cargo delivery by road transport, certain specific parameters must be met to ensure the operational effectiveness.

To solve the given problem, the delivery of bioproducts was considered, as the most difficult example for delivery planning that requires solving the widest range of problems. At the beginning of the formation of the logistics chain of delivering a shipment of these special cargoes by road, individual samples should be collected, and their appropriate packing with the addition of refrigerants should be provided. The formation of loading units and freight shipments for delivery by road has to be carried out by criterion of a minimum of total costs. Therefore, the optimal plan for delivery by road should be determined, which includes determining the optimal number of loading units by type of packaging and freight shipments delivered from each pick-up point to the central warehouse in the air terminal.

For each day and each shipping point, the number of bioproduct samples to be delivered to the central warehouse, as well as the number and type of packages and the size of cargo shipments must be determined.

The urgency of shipments and the possibility of their storage at departure points must be taken into account, and the choice of road carriers must be ensured. As part of the task, the minimum total cost of delivery during the planning period will be the criterion of optimality. Whereas, by delivery we mean a broad interpretation of the term, including providing packaging of cargo, stuffing the cargo with dry ice, its service during delivery process, ensuring proper conditions and technologies of storage, as well as long-haul transportation.

In the problem statement the following conventions are used:

$i \in I$ – index of the point of departure of bioproducts' samples;

J – total number of destinations for samples of bioproducts;

h_{ij}^t – number of samples of bioproducts taken on day t and to be delivered to the point j;

h_{ij}^{Qt} – number of bioproducts' samples to be sent urgently: $h_{ij}^{Qt} \le h_{ij}^t$;

c_i^t – total cost of packaging and refrigerants (dry ice) at standard terms of transportation;

Δh_i^t – total number of bioproducts' samples remained in storage after the day t;

Δh_{ij}^t – number of samples of bioproducts products that remained in storage after the day t and which must be sent to the destination j;

v_i^t – total volume of packages that were shipped on day t;

g_i^t – total mass of packages sent on day t;

S_i – function of storage costs (mainly the cost of dry ice) depending on the number of samples of stored bioproducts;

$C_i^{\rho_t}$ – function of transportation costs of the carrier π depending on the total volume and mass of packaged samples of bioproducts for day t;

$\underline{c}_p$ – cost of the packing option $p \in P$ together with dry ice;

k_{ijp}^t – total number of packages of the option p to be used in point i on day t to send in the direction j;

k_{ijp}^{Qt} –number of packages of the option p to be used in point i on day t for urgent shipment in the direction j;

v_p – volume of the packing option $p \in P$;

$\underline{g}_p$ – mass of the packing option $p \in P$ together with dry ice;

g_1 – average mass of one sample;

d_{ij}^t – number of samples sent from the point i on day t in the direction j;

$\overline{d}_p$ – maximum number of samples contained in the package p;

Π_i – set of possible carriers π for the point of departure i;

π_i^t – carrier for the day t.

A formal record of the problem is presented:

$$\min_{d_{ij}^t, k_{ijp}^t, \pi_i^t} \sum_{t \in T} \left(c_i^t + S_i(\Delta h_i^t) + C_i^{\pi_t}(v_i^t, g_i^t) \right). \quad (1)$$

$$d_{ij}^t = h_{ij}^t - \Delta h_{ij}^t + \Delta h_{ij}^{t-1},\ d_{ij}^t \ge \Delta h_{ij}^{t-1} + h_{ij}^{Qt},$$
$$j \in J,\ i \in I,\ t \in T \quad (2)$$

$$\sum_{p \in P} \overline{d}_p k_{ijp}^t \ge d_{ij}^t,\ \ j \in J,\ i \in I,\ t \in T. \quad (3)$$

$$\sum_{p \in P} \overline{d}_p k_{ijp}^{Qt} \ge h_{ij}^{Qt},\ \ j \in J,\ i \in I,\ t \in T. \quad (4)$$

$$k_{ijp}^t \ge k_{ijp}^{Qt},\ \ p \in P,\ j \in J,\ i \in I,\ t \in T. \quad (5)$$

$$c_i^t = \sum_{p \in P} \underline{c}_p \sum_{j \in J} k_{ijp}^t,\quad i \in I,\ t \in T. \quad (6)$$

$$\Delta h_i^t = \sum_{j \in J} \Delta h_{ij}^t,\quad i \in I,\ t \in T. \quad (7)$$

$$v_i^t = \sum_{p \in P} v_p \sum_{j \in J} k_{ijp}^t,\quad i \in I,\ t \in T. \quad (8)$$

$$g_i^t = \sum_{p \in P} \underline{g}_p \sum_{j \in J} k_{ijp}^t + g_1 \sum_{j \in J} d_{ij}^t, \quad i \in I,\, t \in T. \tag{9}$$

$$\Delta h_{ij}^t = 0,\ 1,\ 2, \ldots \text{ integers};$$

$$j \in J,\, i \in I,\, t \in T. \tag{10}$$

$$k_{ijp}^t = 0, 1, 2, \ldots \text{ integers}, \quad k_{ijp}^{Qt} = 0,\ 1,\ 2, \ldots \text{ integers};$$
$$p \in P,\ j \in J,\, i \in I,\, t \in T. \tag{11}$$

$$\Delta h_{ij}^0 = 0,\ \Delta h_{ij}^{T+1} = 0,\ \ i \in I,\ j \in J. \tag{12}$$

$$\pi_i^t \in \Pi_i,\ i \in I. \tag{13}$$

The delivery process is considered for a given period. When making calculations, one or more months, a quarter, a year can be taken as a planning period T. Herewith, the planning period is divided into separate days t. For each day the need to send samples of bioproducts is set, where h_{ij}^t – number of samples, $i \in I$ – customer index (point of departure), and $j \in J$ –destination index of each sample. The condition that the shipment is performed in one batch not more than once a day but it may not be carried out on all days of the week was made. In this case, unsent samples of bioproducts can be stored within 24 hours. It follows that the need h_{ij}^t for shipping on day t may not be equal to sending d_{ij}^t on that day, which allows to more efficiently organize delivery. However, part of the samples $h_{ij}^{Qt} \le h_{ij}^t$ must be shipped urgently due to the specific properties that can be lost during storage and cannot be left for shipment the next day. The type of sample itself and tests to be delivered do not matter in terms of weight parameters, as mass and volume of the bioproduct sample itself are not substantial.

Depending on the number of samples of bioproducts d_{ij}^t that are sent from the point i on day t, there is a need to choose the option of packaging samples. The selected packaging option is described by mass g_i^t, volume v_i^t and cost of packaging samples c_i^t. In the case when the number of samples of bioproducts d_{ij}^t exceeds the capacity of the maximum packaging, it is necessary to distribute the total number of samples of bioproducts d_{ij}^t as best as possible between packaging options. This can be done as follows. Let the number of packaging options is equal to P, each option $p \in P$ is characterized by the maximum number of samples of bioproducts $\overline{d}_p$ that it can contain, as well as the external volume v_p, mass of the package $\underline{g}_p$ with dry ice and costs of packaging $\underline{c}_p$ with dry ice. To successfully solve the problem, a slight simplification should be allowed, which is the assumption that the amount of dry ice does not depend on the number of samples in the package. This simplification is not significant as such dependence is insignificant given the multiple excess of the dry ice mass in the comparison with the samples of bioproducts. Also it was taken into account that the amount of dry ice can vary, in particular, depending on the season of the year and the expected time of delivery to the final destination.

The task for the general planning period T is to determine for each day $t \in T$ and each point of departure $i \in I$ how many samples of bioproducts d_{ij}^t will be sent on that day to the central warehouse, and how this quantity will be distributed on packages, which carrier to choose based on the criterion of minimum cost for packaging and dry ice, additional dry ice and storage and for the transportation itself during the planning period.

In conducting the calculations, delivery of bioproducts was considered from three points of departure, located at different distances from the central warehouse, while at the same time there were four points of destination. At the same time, two delivery options were considered for each point of departure and two options for shipping cargo from the central warehouse to the destination points by air.

4. Discussions

Despite the significant interest of participants of global supply chains in the Ukrainian market and there are still a number of unresolved problems that slow down this integration process. Primarily, these are infrastructure problems, as well as the search for a reliable partner to provide global chains of emergence in Ukraine. Clustering should be considered as one of the most effective innovative integrated tools and basic economic principles cargo delivery management in global supply chains. It is the creation of logistics clusters that allows for the integration of urban transport flows and global supply chains.

Currently, urban logistics clusters are being successfully developed, which include logistics infrastructure facilities combined according to the principles of integrated logistics. Although a comprehensive combination of rail, maritime, road and air transport remains a rarity, such logistics clusters already exist, for example in Hong Kong. The greatest difficulty is to include maritime and air transport modes in such clusters. Ports cannot exist anywhere, for this there must be water areas or arteries and other conditions. Leading ports in most cities are already becoming part of the integrated logistics infrastructure and other components of the urban logistics cluster definitely depend on their operation. Urban logistics clusters are actively developing due to the further spread of globalization trends to all aspects of the economy.

The integration of the logistics infrastructure of cities will continue to strengthen, and this trend will be typical for Ukraine as well. The embryonic formation in Odessa, Mykolaiv and Yuzhny of urban logistics clusters can be mentioned, which are designed to integrate freight flows on different modes of transport, with the active use of logistics infrastructure, especially warehouses. The problem of domestic ports is the significant diversity of different modules of the city's logistics infrastructure, and therefore the formation of a single logistics cluster of the city is complicated. The issue of cargo flows integration in multimodal and other combination of transport modes in Ukraine is due to significant deviations in the parameters of their operation and development. It can be argued that there are only a few examples of effective cooperation between rail and maritime modes of transport.

At the same time, cargo flows served by air transport are more integrated into the supply chain. This is caused by many factors, primarily the fact that cargo owners focus on air transport based on its speed advantages, and downtimes in other parts of the logistics chain level it off. It should also be noted that air transport carries more expensive cargoes, which requires compliance with higher standards of delivery reliability. Air transport, like maritime transport, is a mainline mode of transport, and therefore such modes must a priori involve other transport modes, at least road transport. Creation of logistic cluster will minimize the delivery time of shipments and ensure the increase of their safety, since the greatest risks of failure to reliability of shipments exist on the intersection of transport modes. Also it gives logistic operators the opportunity to fully implement the "door to door" logistics principle. In addition, the use of such clusters can minimize the cost of delivery in the global logistics chain on the whole. The current issues of logistic clusters' development in Ukraine can be divided and systematized into two aspects (Fig. 1).

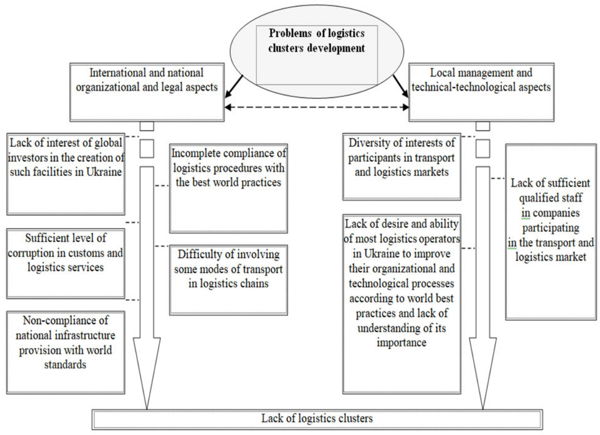

Fig. 1 Challenges of logistics clusters' development.

International and national organizational and legal aspects are characterized by: lack of interest of global investors in the creation of such facilities in Ukraine, high level of corruption in customs and logistics services, non-compliance of national infrastructure with international standards, incomplete compliance of logistics procedures with the best practices, as well as the difficulty of involving certain modes of transport in logistics chains (for example, railways for the delivery of special categories of goods with significantly limited storage time).

While local management and technical-technological aspects are characterized by a divergence of interests of participants in transport and logistics markets, lack of desire and ability of most logistics operators in Ukraine to improve their organizational and technological processes according to world best practices and lack of understanding of this, lack of sufficient number of competent personnel in companies participating in the transport and logistics market, etc.

All this leads to the absence of these innovative objects of transport and logistics infrastructure in national economy, which has an extremely negative impact on the prospects for the development of urban logistics infrastructure in general.

5. Conclusions

In setting the objectives of the study, it was determined that the organization of delivering special categories of goods becomes a key to success under the globalization of supply chains. It was determined that it is necessary to focus on the development of a mathematical apparatus and to the formation of a economic principles cargo delivery management of special categories of goods by road. For the fullest understanding of the problem, the delivery of bioproducts was chosen as the most difficult example of the solution. As part of the set task the optimal plan for delivery of bioproducts by road was determined, which include establishing the optimal number of loading units by type of packaging and freight shipments delivered from each pick-up point to the central warehouse in the aviation terminal. The practical value of the proposed mathematical model is characterized by the simplicity of its application by logistics operators, while its relevance is difficult to overestimate in terms of COVID-19 spread in the world.

Logistics clusters are the foundation of global supply chains, which means their development in Ukraine is vital. They have been studied thoroughly as one of the key tools for innovative development of logistics infrastructure. It was emphasized that their successful development is due to the further spread of globalization trends to all aspects of the economy. Challenges of logistics clusters' development in Ukraine were identified and systematized. International and national organizational-legal and local managerial and technical-technological aspects of these problems were highlighted and described.

According to the results of the conducted study the authors conclude that the minimum sufficient level of integration for the logistics operator in providing the delivery described in the paper is the level of a complex logistics operator, that is, the highest level of 3 PL logistics operator. Obviously, the lower level 3 PL logistics operators, namely, transport and logistics operator, which provides freight forwarding and transportation management is not enough. At the same time, it is clear that the more advanced level 4 PL logistics operators, namely the supply chain systems integrator and aggregator of these chains, will have a significant advantage in practice.

A perfect unified information and communication system will allow companies operating in the port to offer a wider range of services and optimize information exchange between all users of the system, including service companies and management. The creation of a single data exchange center in the ports will ensure the speed and reliability of data exchange in the organization of any cargo operations, as well as ensure a reduction in downtime and an uninterrupted transport and distribution process, thus reducing the time and costs of operations for servicing and transporting cargo. In addition, this system will allow all users of port services to reduce the time for filling out customs documentation through electronic submission of information about the cargo (declaring cargo and containers). Considering the above, the information and communication system will increase the level of competitiveness of the port in the international market by optimizing information flows and business processes. Subsequent studies will focus on the development of a mechanism for enhancing the implementation of information and communication technologies and the creation of a single data exchange center.

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